ACTIVITY REPORT

March 2004

Natural Gas & Oil Technology Partnership

Bringing Department of Energy national laboratories capabilities to the petroleum industry.

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Note: Natural Gas and Oil Technology Partnership projects are reported according to the following schedule:

January, March, May, July, September, November	**February, April, June, August, October, December**
Drilling, Completion, and Stimulation Technology	Upstream Environmental Technology
Oil and Gas Recovery Technology	Downstream Environmental Technology
Diagnostic and Imaging Technology	Natural Gas Technology

Natural Gas and Oil Technology Partnership on the World Wide Web: http://www.sandia.gov/ngotp/

Drilling, Completion, and Stimulation Technology

Seismic Source for Pore Pressure Prediction While Drilling

(Halliburton and INEEL)

Highlight:

- Final CDDS test series completed at RMOTC

The Capacitive Discharge Downhole Source (CDDS) completed its final test series at the Department of Energy (DOE) Rocky Mountain Oilfield Testing Center (RMOTC) in Casper, WY on March 2, 2004. The objective of this last test was to attempt velocity contrast detection between shale and a sand stone unit located about 900 feet below the surface in an oil-bearing formation. RMOTC allowed us to piggyback on preparations for another high pressure drilling experiment to be conducted at a later date. The drilling operator produced a 12" uncased well down to 546 feet, cleaned it, and then pulled out. We had access to the well for a testing interval that lasted eight hours.

Twelve hydrophones were deployed down the mud/polymer filled hole starting at the 44 meter level and going up to the 32 meter level. Thirty six geophones were deployed at the surface starting at the well and going out to 108 meters at 3 meter spacing. The CDDS was deployed using a wireline. One hundred and eighty nine CDDS shots were taken at regular intervals going down from the bottom of the geophone string to the bottom of the well and then repeated on the way back up. Ten shots were taken with the tool resting on the bottom of the well. The drilling operation was completely shut down during the test interval and the drill crew was walking on pins and needles in order to prevent unwanted background noise. RMOTC and the drilling crew deserve a lot of credit for their cooperation. The next step is to analyze the data and finish the final report.

Acoustic Telemetry (MWD) Drilling

(ABB, Electroacoustics Research Laboratory, Extreme Engineering, and SNL)

This project is in “Close out” status.

Effects of Well Conditions on Post-Perforation Permeability

(Halliburton, Penn State, and LLNL)

Highlight:

- Publications presented at SPE International Symposium

We presented results from recent physcial and computational experiments at the SPE International Symposium and Exhibition on Formation Damage Control Symposium held February 18-20, 2004 in Lafayette, Louisiana. Publications presented at the Symposium include:

Detwiler, R.L., J.P. Morris, O. Karacan, P.M. Halleck, and J. Hardesty, Evaluation of the Relative Importance of Parameters Influencing Perforation Cleanup, SPE 86538, International Symposium and Exhibition on Formation Damage Control Symposium, Lafayette, Louisiana, Feb. 18-20, 2004.

Halleck, P.M., C.O. Karacan, J. Hardesty, and R.L. Detwiler, Changes in Perforation-Induced Formation Damage With Degree of Underbalance: Comparison of Sandstone and Limestone Formations, SPE 86541, International Symposium and Exhibition on Formation Damage Control Symposium, Lafayette, Louisiana, Feb. 18-20, 2004.

We are currently in the process of preparing our final report for this project.

Automatic Flaw Detection and Identification for Coiled Tubing

(U of Tulsa, INEEL)

No report received.

Laboratory Study on Borehole Stability and Sand Production in Weakly Cemented Sand

(ChevronTexaco, Shell, and LBNL)

We continue to measure the mechanical and kilohertz range acoustic properties of weakly-cemented sand samples using calcium aluminate cemented sand. The cement and sand are mixed together by using weakly concentrated cement suspension in water. We control the sample porosity by consolidating a column of sand/cement mixture via vibration. This procedure appears to reduce the heterogeneity in the cementation of the samples compared to the previous procedure which used mechanical compaction.

One of the problems in measuring the mechanical and acoustic properties of weakly-cemented sand samples under confining stresses is that these samples are difficult to handle without damaging the surface and altering the geometry. Many borehole breakout experiments using the true triaxial compression test cell built in this project were not successful because the samples were unevenly loaded through damaged surfaces. We are currently seeking a reliable technique to reduce this problem, e.g., placing a rubber membrane on the sample-loading platen interfaces without hindering the flow of fluid from the platens into the sample.

Development of Smart-Proppant Technology for Hydraulic Fracturing

(U of Tulsa, Halliburton Energy Services, and INEEL)

Project Manager Arthur D. Watkins reports:

During this reporting period, the first activity was the development of a new budget plan that was submitted to financial planning. This plan included a major re-planning of researches due to the large cut in researching funding received from DOE. Next, we prepared for and attended our bi-annual Industrial partner meeting hosted at University of Tulsa, September 18, 2003. The presentations went well and were well accepted. In addition, we have been able to restart the research efforts after the long funding lapse. Per our discussions this Spring with our research partner, Steve Tipton of Univ. of Tulsa, we were able to setup a quick experiment to collect signal integrity data with relationship to tube liftoff for CT-1 and CT-2 test tubes. This data was collected at three amperage levels 5, 6, and 7, at a speed of 700 mm/s. It is planned that this data will be reduced in October's activities. Furthermore, initial correlations for defect detection for data taken this Spring were received from Univ. of Tulsa. These correlations were based on spike height, width, etc. Nevertheless, some key correlation sets for CT-1 and CT-2 have not been received to date. An effort to reduce this data is currently underway.

Project Manager Greg Bala reports:

Representative microbiological systems selected for experimentation have been augmented by a volunteer culture that exhibits the capability to liquefy 3% guar solutions at elevated temperatures (+ 60°C). The organism has been evaluated for salient characteristics and found to be functional at reduced oxygen tensions, capable of spore formation, and able to be maintained on simple media without loss of phenotype.

The liquefaction of guar associated with this culture is superior to micro-organisms purchased to date.

We hypothesize that the enzymatic systems responsible for guar degradation are inducible and not constitutive. Biomass has been prepared and shipped to the University of Tulsa for encapsulation in appropriate carrier beads for further evaluation. Information on the development and characterization of the carrier material has been previously reported. Organisms were prepared by growth in one-half strength trypticase soy broth for 24 hours at 60° followed by triplicate washing in 0.1 M phosphate buffer at pH 7.0. Previous studies have demonstrated that following growth on dilute synthetic media, the cells are capable of guar degradation after a prolonged lag phase. Initial encapsulation will occur during the manufacturing of the beads. Manufacturing should be complete by the second week of December 2004.

Application of High-Powered Lasers to Drilling and Completing Deep Wells

(Parker Geosciences, Colorado School of Mines, Gas Technology Institute, Halliburton Energy Services, and PDVSA, and ANL)

Highlight:

- Two papers submitted to ICALEO'04 Conference

No laser rock testing work scheduled this reporting period. Project is awaiting further funding. The following two papers have been submitted to the 23nd International Congress on Applications of Lasers and Electro-optics, October 4-7, 2004, San Francisco, California:

1."Laser Spallation of Rocks for Oil Well Drilling" Zhiyue Xu and Claude B. Reed, Argonne National Laboratory, Argonne, IL 60439, USA, Richard Parker, Parker Geosciences, LLC, Ramona Graves, Colorado School of Mines

2. "Rock Perforation by Pulsed Nd:YAG Laser", Zhiyue Xu and Claude B. Reed, Argonne National Laboratory, Argonne, IL 60439, USA, Richard Parker, Parker Geosciences, LLC, Ramona Graves, Colorado School of Mines

Lifetime Performance Monitoring of Synthetic Fiber Mooring Ropes

(Shell Global Solutions U.S., Whitehill Manufacturing Corp., Puget Sound Rope, Petroleum Composites, ORNL)

There was no significant reportable progress during the reporting period. We are awaiting FY2004 funding.

Oil and Gas Recovery Technology

Measuring Sucker Rod Pump Parameters Downhole

(Harbison-Fischer, UT-Austin, and SNL)

Highlight:

- Instrumented pump for Texas Tech fabricated

The pump fabricated by Harbison-Fischer for Texas Tech has been checked out and minor changes are being made. Miscellaneous parts are being acquired. The unit will be ready by April 2004 when Texas Tech plans field testing.

Direct Simulation of Near-Wellbore Mechanics

(ChevronTexaco, Halliburton, Schlumberger, Shell, MIT, NM Tech, and SNL)

The focus of our efforts during this project period was preparing for the project workshop held in Houston on March 25-26, 2004. The purpose of the workshop was to demonstrate our 2D and 3D models to our CRADA partners and update both our CRADA and NGOTP partners on the status of our research program. Towards this end, we invested heavily during the project period on developing a series of simulation tutorials for the 2D code and finalizing the development of the beta version of the 3D code. We also completed the analysis and documentation of the initial series of sanding simulations so that we could disseminate these results to partners at the workshop.

Staff from all four CRADA partners (ChevronTexaco, Halliburton, Schlumberger, and Shell) attended the modeling workshop held on March 25th. The workshop provided an introduction to the functionality and application of both the 2D and 3D codes, as well as modeling tutorials for synthetic specimen testing and coupled fluid simulation. Feedback from the partners was positive and included specific suggestions for the future enhancement of model functionality.

A related NGOTP project meeting was held on March 26th. Attendees included all CRADA companies as well as staff from BP. Project progress was summarized by Sandia staff Ben Cook and David Boutt and guidance was solicited on the project's future focus and funding structure. Specific guidance from partners included the following recommendations: (1) an extension of the sanding simulation study to include larger models (to evaluate boundary effects) and sensitivity study of the influence of particle size to perforation diameter ratio; (2) a related code enhancement effort to improve the bonding model and computational efficiency of the 2D code; (3) an extended validation effort to explore such fundamental areas as the code's ability to predict the effective viscosity of particle-laden (slurry) flows; and (4) an exploratory program development effort to determine industry interest in a continuation JIP program focusing on the expanded application of the codes to sanding and related near-wellbore problems. Both meetings were hosted by CRADA partner ChevronTexaco.

Well Integrity Assurance for Sub-Salt and Near-Salt Deepwater GoM Reservoirs

(BHP, BP Amoco, ChevronTexaco, ConocoPhillips, ExxonMobil,Halliburton, Kerr-McGee, Shell, and SNL)

A new phase of the reservoir-scale finite element modeling task was initiated to examine the response of adjacent and overlying salt diapers to pore pressure depletion and reservoir compaction. Based upon the positive reception to the salt loading on casing software that was released to the partners earlier in the year, the wellbore scale modeling effort is being extended to consider multiple salt constitutive behavior, as well as several additional casing/hole configurations. Work also continued on the task focused on constraining the constitutive properties of deepwater GoM salt diapers. Approximately thirty more GoM salt cuttings samples were analyzed. The database now includes over one hundred samples. In addition, samples from several SPR sites were collected and are in the process of being analyzed.

Single-company project meetings were held at ConocoPhillips, BP, and Kerr-McGee in February. In addition, individual meetings were conducted with staff from ExxonMobil and Eni Petroleum. Finally, a paper entitled "Geomechanical modeling of complex reservoirs: Recent les-

sons and current state of the art" was presented by J. T. Fredrich at the AAPG Hedberg Conference "Structural Diagenesis: Fundamental Advances and New Applications from a Holistic View of Mechanical and Chemical Processes", which convened in Austin, Texas on February 8-11. Invoices were sent to each of the seven participating companies for their fourth year JIP participation, with payment already received from several participants.

An Integrated Approach to Assessing Seismic Stimulation

(Aera Energy, ASR, BP Amoco, ChevronTexaco, ConocoPhillips, Halliburton, Marathon, OGCI, Piezo Sona-Tool, Schlumberger, Shell, UC-Berkeley, LBNL, and LANL)

Single-phase water flow experiments are in progress at LANL using a Fontainebleau sandstone core sample, which is free of natural in-situ clay particles. Background permeability is roughly 5 millidarcys. Mechanical stress stimulation at 25 to 50 Hz shows very small effects on the absolute permeability. Suspensions of 0.3 micron diameter particles in water will be injected into the sample next to measure their impact on background permeability and then to observe their retention and release during stress stimulation. This mechanism is also being studied at the microscopic scale using an automated digital video system.

In the field work this past month, LBNL monitored a seismic stimulation at the Oxy Inc. Elk Hills oil field in Southern California. Three different wells were occupied with the LBNL multicomponent sensor (vertical and horizontal geophone and wide band hydrophone [2 sec to 10,000 hz] in one package) to monitor pressure and particle motion. The team monitored the response at reservoir depth of the ASR system (pressure pulse in injection wells at distances of over 1000 feet away). The objective of the work was to look for a fluid coupled response that is predicted from the theoretical work being carried out at UC Berkeley. The data are now being processed to examine the bandwidth and amplitude of the response.

Direct Quantification of Uncertainties Associated with Reservoir Performance

(ChevronTexaco and LANL)

No work scheduled this reporting period. Project awaiting further funding.

Diagnostic and Imaging Technology

Next-Generation Seismic Modeling and Imaging

(Advanced Data Solutions, Anadarko, BHP Petroleum, BP Amoco, ChevronTexaco, Conoco, Core Laboratories/Tomoseis, ExxonMobil, Fairfield Industries, Fugro Geoservices, GeoCenter, Geophysical Development, GX Technology, Marathon, Mitchell Energy, Paradigm Geophysical, PGS, Phillips, Shell, Unocal, Veritas DGC, WesternGeco, Society of Exploration Geophysicists, Stanford University, U of Houston, Veritas DGC, LLNL)

Highlights:

- 3-D Elastic data computations continued in SEG/EAEG salt structure
- Elastic data computations to be reported at professional meeting

3-D elastic data computations have continued in the SEG/EAEG salt structure. A total of 132 shots of full model (termed "Phase 2") calculations have now been completed. This represents a total of 150,000 CPU-hours of computing, which, if obtained commercially, would have cost about $300K. Calculations for each shot produced about 1 GB of data.About half of the snaphots are the computed traces; the rest are the series of wavefront snapshots that are also produced. These snapshots are vital for correctly understanding the complexity of the elastic wave propagation effects in this structure.

An expanded abstract that describes the results of the Phase 2 modeling has been submitted for presentation at the 2004 Annual Meeting of the Society of Exploration Geophysicists, to be held October 10-15, 2004. The details follow:

"Next-Generation Seismic Modeling and Imaging project: Summary of elastic modeling results" - submitted for presentation at 74th Annual Meeting, Society of Exploration Geophysicists, (October 10-15, 2004).

Inversion of Full Waveform Seismic Data for 3D Elastic Parameters

(Amerada Hess, ChevronTexaco, Conoco, Fairfield Industries, GX Technology, Marathon, Unocal, SNL)

Project on funding hold. No report this month.

Innovative Wave-Equation Migration

(Advanced Data Solutions, Amerada-Hess, Applied Geophysics Services, Baker Atlas, BHP, ConocoPhillips, ExxonMobil, FairfieldIndustries, GX Technology, Petroleum GeoServices, Screen Imaging, Shell, TomoSeis, Unocal, Veritas DGC, and LANL)

Highlights:

- SEG expanded abstracts prepared to report project progress
- Work continuing on stationary-phase wave-equation migration

We prepared three SEG expanded abstracts to be submitted to the 2004 SEG Annual Meeting. They are: (1) Controlled-aperture wavepath wave-equation migration; (2) Offset-domain globally optimized Fourier finite-difference migration; (3) Stationary-phase wave-equation migration. These papers contain the most recent research results of the project.

We are implementing and testing the stationary-phase wave-equation migration using a 3D synthetic dataset from the SEG/EAGE salt model. Our preliminary results indicate that the efficient stationary-phase wave-equation migration can produce more accurate images than the conventional common-azimuth migration. We conducted research on development of 3D plane-wave wave-equation migration for significantly improving 3D migration efficiency while maintaining migration accuracy. We also investigated how to obtain more physical information from migration images that could be valuable for reliable reservoir characterization.

Testing and Validation of High-Resolution Fluid Imaging in Real Time

(DeepLook, KMS Technologies, KJT Enterprises, U of Wisconsin, LBNL, and SNL)

No report received.

Autonomous Monitoring of Production

(Aera Energy, ChevronTexaco, SteamTech Environmental Services, TomoSeis, and LLNL)

We have completed the processing and interpretation of results at the Vacuum Field. Results have been incorporated in a paper being prepared for publication in a technical journal. Our objective is to make the technology accessible to those companies that can benefit from it and can use it. We have chosen The Leading Edge as a forum for communicating to the community. Two papers have been submitted for publication in that trade journal; one on the general topic of electrical resistance tomography and the other on the specialized subject of autonomous monitoring of a deep reservoir using casings as long electrodes. The latter paper will include a section on autonomous monitoring of reservoir processes.

Some of the methods of noise reduction and equipment safety have been implemented in field trials for about two months. The methods are working well and have been discussed in the papers submitted to The Leading Edge.

Anisotropic Properties of Compacted Clay-Rich Rocks

(BP Amoco, ChevronTexaco, ConocoPhillips, and LBNL)

No report received.

Realistic Anisotropic Velocity Estimation in Complex 3D Environments

(BP Amoco, ChevronTexaco, ConocoPhillips, Kerr-McGee, Shell, TomoSeis, and LBNL)

In seismic data processing, it is common to use a non-hyperbolic travel time approximation assuming weak anisotropy in a transversely isotropic medium with vertical symmetry axis (VTI). Two non-hyperbolic travel time approximation equations which are used in velocity analysis in VTI media have been proposed by Alkhalifah and Tsvankin (1995) and Grechka and Tsvankin (1997). They have the correct short-spread (normal) moveout velocity, but higher-order terms in offset-squared are only approximations.

Recently Stovas et al. (2004) presented a new approximation for the reflection travel times for a transverse isotropic media that does not use the weak-anisotropy assumption. The comparison with the Alkhalifah and Tsvankin (1995) nonhyperbolic approximation for single reflector models shows that the Stovas et al. method is more accurate. However they have not yet used their new equation to estimate anisotropic parameters.

Work is under way to use Stovas's equation to estimate anisotropic parameters from realistic 2D VTI anisotropic synthetic data and compare the results with those obtained using the Alkhalifah and Tsvankin (1995) and Grechka and Tsvankin(1997) methods. Based on Stovas's idea, we are developing a non-hyperbolic travel time approximation for tilted transversely isotropic medium for the estimation of Thomson parameters.

Joint Geophysical Imaging

(ChevronTexaco, Core Laboratories, Electromagnetic Instruments, ExxonMobil, and LBNL)

The objectives of this research are two-fold. First, to investigate the feasibility of simultaneously inverting different types of geophysical data (electromagnetic and seismic) linked through a rock physics model to produce a single self-consistent reservoir model of hydrologic parameters (porosity, fluid and gas saturations etc.) rather than geophysical parameters. Second, if such an inversion is feasible, to develop specific algorithms to use surface (land or marine) data and assess these algorithms in terms of parameter resolution and computational requirements.

This last month we have continued to focus on improving the computational performance of the 3D EM modeling and inversion codes that will be coupled with AVO seismic codes for the Joint Inversion Project. We have now implemented a framework for preconditioning non-linear 3D electromagnetic inverse scattering problems using conjugate gradient (NLCG) and limited memory quasi-Newton (LM-BFGS) methods. The key to our approach is the use of approximate adjoint method that allows for an economical approximation of the Hessian. Using this approximate Hessian as a preconditoner, we show that the preconditioned NLCG iteration converges significantly faster than the non-preconditioned iteration as well as converging to a data misfit level below that observed for the non-preconditioned problem. Similar conclusions are also observed for the LM-BFGS method when an approximate Hessian is used instead of a scaled identity matrix in the inversion iteration. Unfortunately, we do not see the anticipated benefit of using preconditioned LM-BFGS scheme over a preconditioned NLCG scheme. For both preconditioned schemes, convergence performance appears to be similar. A possible indicator of this outcome is the behavior of the line search within the LM-BFGS iteration. It was anticipated that near convergence, a step size of one would be generated. What was observed, instead, were step lengths that are nowhere near one, indicating the Hessian approximations built up from the previous inversion iterations are not that effective in generating a search direction converging to the Newton direction. These efforts in preconditioning will be applied to inverting joint marine data sets in the coming months.